VALIDATED CEMENTED SOCKET MODEL FOR OPTIMISING ACETABULAR FIXATION

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Introduction

The total hip replacement (THR) is the second most successful and cost-effective surgical procedure of all time. Over the last few decades patients have developed considerably higher expectations after joint replacement and are demanding earlier joint replacement surgery. The registry data from both Sweden and the UK show that cemented hip cups have a superior survival compared to cementless hip sockets. Much research has focused on the stem design and fixation, but the data shows that hip cup failure is the greater problem. The focus of this study is to improve methods of cemented cup fixation through validation experiments and finite element analysis (FEA).

Methods

Experimental testing was conducted on five Sawbones composite pelves (4th generation, model 3405). A custom 3D printed jig was used to drill four 8 mm bolt holes at the superior part of the sacroiliac joint, used later for clamping. The pelves were reamed to a diameter of 60 mm in a CNC machine. The cups were machined out of a bar of UHMWPE (TIVAR 1000) to inner and outer diameters of 28 mm and 54 mm respectively. Surgical Simplex P cement (Stryker) was vacuum mixed at room temperature, to fix the cup to the acetabulum. A custom jig ensured a mantle thickness of 3 mm and cup positioning of 45° abduction and 10° anteversion. [1] Each composite pelvis was instrumented with triaxial strain gauges (SGD-2/350-RY63, Omega Engineering Limited) at four different locations of high predicted strain. The samples were bolted securely in the uniaxial testing machine (Series 5965 with a 5 kN load cell; Instron) with the loading vector *F* in the direction of the peak force during normal walking (Figure 1). [2]

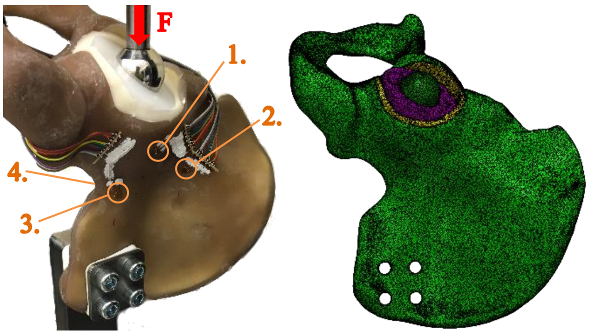

Figure 1: Left – Experimental setup showing location of strain gauges. Right – finite element mesh.

After preconditioning load was applied to the each construct through a 28 mm metal head up to 500 N in increments of 50 N, for a total of five repetitions. The directional surface strains were used to evaluate the equivalent strain. Specimen specific finite element models were developed based on CT scan data using ScanIP (2016.09 Synopsis Inc.). The images were obtained using a micro CT scanner (XTH225ST, Nikon Metrology UK). The mesh (Figure 2) consisted of an average of 760 thousand linear tetrahedral elements and was solved in ANSYS APDL 15.0.

Results and Discussion

The equivalent strain at each location was repeatable for each pelvis but varied within the group (Figure 2).

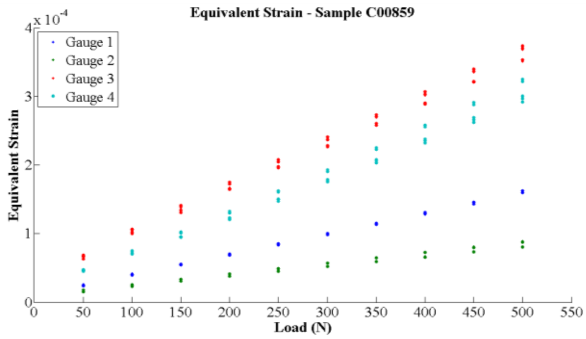

Figure 2: Typical plot of strain against load (n = 5).

This could be caused either by the variation in mechanical properties between the pelves, or the sensitivity of the gauges to positioning. The agreement between the predicted and experimental equivalent strains was good. Hence, validating this specific methodology of conducting finite element analyses of the pelvis based on CT image data. The next stage is to use the same methodology to develop a patient specific FEA model, including a bone remodeling algorithm and muscle forces, based on the CT images already obtained (VHP). This model will be used to optimize the cemented fixation and would be verified experimentally using composite pelves. This research is aimed at informing clinical practice and enhancing longterm cemented fixation. Reducing the need for revision surgery will greatly improve patient quality of life, whilst also reducing the burden on the healthcare delivery system.

References

1. Zhang QH et al, J Biomech 43(14):2722-2727, 2010
2. Heller M et al, J Biomech 34(7):883-893, 2001